USE OF THE EPA SWMM FOR CONTINUOUS SIMULATION

by Wayne C. Huber

CONTINUOUS AND SINGLE EVENT SIMULATION

The original EPA Storm Water Management Model (SWMM) was designed for single event simulation, producing detailed (i.e., short time increment) hydrographs and pollutographs for individual storms. Although this capability remains, the model has now been altered so that it may be run for an unlimited number of time steps, i.e., continuously. In this mode it may be used in planning, that is, for an overall assessment of urban runoff problems and estimates of the effectiveness and costs of abatement procedures. Trade-offs among various control options (e.g., storage, treatment, and street sweeping) may be evaluated. Complex interactions between the meteorology (e.g., precipitation patterns) and the hydrology of an area may be simulated without resorting to average values or very simplified methods. In this manner, critical events from the long period of simulation may be selected for detailed analysis. In addition, return periods for intensity, duration, and volume (mass) of runoff (pollutant loads) may be assigned on the basis of the simulated record instead of equating them to the same statistics of the rainfall record. In this manner, the critical events chosen for study may be substituted for hypothetical "design storms," the latter often synthesized from intensity-duration-frequency curves on the basis of questionable statistical assumptions. Linsley and Crawford (1974) present a useful discussion of continuous simulation in urban hydrology.

Several continuous simulation models are available for urban runoff analysis. Among the earliest was the Stanford Watershed Model (Crawford and Linsley, 1966), out of which evolved the Hydrocomp Model (Hydrocomp, 1976), a versatile program for natural and agricultural as well as urban areas. It uses a 15-minute time step, as does the Dorsch QQS model

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(Geiger et al., 1976). Probably the most widely used continuous simulation model for urban areas is STORM (Hydrologic Engineering Center, 1976; Roesner et al., 1974), developed by Water Resources Engineers, the City of San Francisco, and the Hydrologic Engineering Center of the Corps of Engineers. It uses one-hour time steps coupled with simplified runoff and pollutant estimation procedures and has been extensively used for planning (e.g., Roesner et al., 1974) and overall urban runoff evaluation (e.g., Heaney et al., 1977). A similar, but even simpler model, still producing useful statistics of long-term urban runoff, is the Simplified Storm Water Management Model developed by Metcalf and Eddy (Lager et al., 1976). Finally, several "first cut" procedures have been developed, based in part upon continuous simulation, but avoiding any computer usage at all (Howard, 1976; Heaney et al., 1976; EPA, 1976).

CONTINUOUS SWMM OVERVIEW

SWMM is run continuously using only the Runoff and Storage/Treatment blocks. Flood routing in the Transport block or the Receiving block is avoided and is unnecessary for the planning purposes to which the model is applied. (However, there is no limitation on the number of time steps for either WRE Transport or Receive.) A "Level III" receiving water model that will couple with either continuous SWMM or STORM has been developed based upon earlier work (Heaney et al., 1977) and is presently being documented (Medina, 1978). The algorithms used in Runoff and Storage/Treatment are almost identical when run continuously or as a single event model; the only (minor) differences occur in the snowmelt routines. A one-hour time step is required when the model receives input from National Weather Service (NWS) precipitation and temperature tapes, as is the case for most applications. Although other time steps may be used, the output generally assumes 24 time steps per day. In fact, inclusion of daily, monthly, and annual totals along with a few other Input/Output features forms just about the only distinction between the continuous and single event mode.

It is anticipated that continuous, long-term simulation will be used only with a very coarse, "lumped" or aggregated catchment schematization in order to minimize computer costs. For example, only one subcatchment and no gutters or pipes in the schematization will often provide relatively accurate results.

SNOWMELT

Following the earlier work of the Canadian SWMM study by Proctor and Redfern and James F. MacLaren (1976a, 1976b), snowmelt simulation has been added for both single event and continuous simulation. Most techniques are drawn from Anderson's (1973) work for the National Weather Service (NWS). For single event simulation, daily maximum-minimum temperatures from the NWS "WBAN Summary of the Day, Deck 345" are converted to hourly values by sinusoidal interpolation.

Urban snow removal practices may be simulated through "redistribution fractions" input for each subcatchment (see figure 1), through alteration of the melt coefficients and base temperatures for the regions of each subcatchment, and through the areal depletion curves used for continuous simulation. Anderson's temperature-index and heat balance melt equations are used for melt computations during dry and rainy periods, respectively. For continuous simulation, the "cold content" of the pack is maintained in order to "ripen" the snow before melting. Routing of melt water through

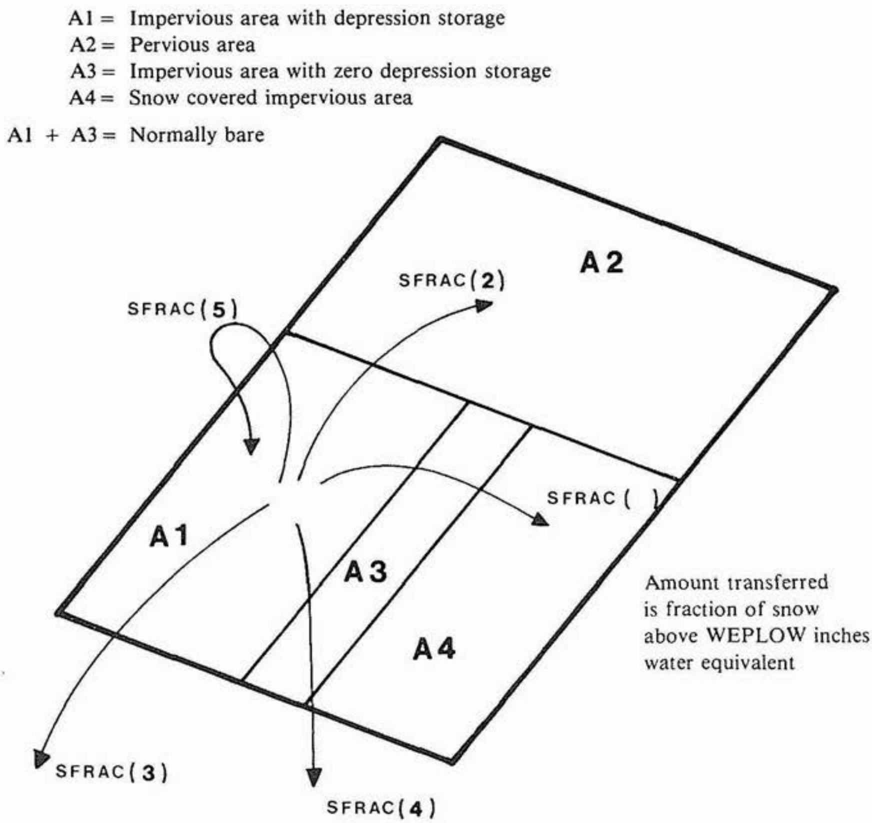

FIG. 1. CATCHMENT SCHEMATIZATION FOR SNOWMELT SIMULATION, indicating redistribution fractions for simulation of snow removal practices. "Normally bare" impervious areas refer to roadways, sidewalks, etc., which will normally be plowed and free of snow.

the snow pack is performed as a simple reservoir routing procedure, as in the Canadian study.

The presence of a snow pack is assumed to have no effect on overland flow processes beneath it. Melt is routed in the same manner as rainfall.

INPUT DATA

Continuous SWMM requires all data entries previously required except that the coarse schematization greatly reduces the number of entries required for subcatchments and gutter/pipes (see below). The primary data requirement is a long-term precipitation record for the area. SWMM is keyed to the use of magnetic tapes available from the National Weather Records Center of the NWS at Asheville, North Carolina. These tapes contain card images of "NWS Card Deck 488, USWB Hourly Precipitation" and cost approximately $75 per station for a 25-year record of hourly precipitation totals. (Similar tapes are supplied in Canada by the Atmospheric Environment Service.) When snowmelt is simulated, a record of daily temperature data is also required; see the previous snowmelt routine documentation. These data are processed in subroutine CTRAIN in Runoff for later use by the other routines in the block. Optionally, the processed data, including a tabulation of the fifty highest values, may be examined before proceeding with the remainder of the simulation. When snowmelt is simulated, rainfall or snowfall is determined from hourly air temperatures synthesized from the daily maximum-minimum values for the station. Snowfall values are keyed as negative precipitation for internal use in the program.

Other input data unique to continuous simulation consist mainly of dates for starting, stopping, and printing. In addition, NWS Station ID numbers must be known for the precipitation and temperature tapes. Generally, input data continue to be in the form described in Version II User's Manual (Huber et al., 1975) with modifications described in interim documentation (Huber et al., 1977).

CATCHMENT SCHEMATIZATION

Guidelines for subcatchment "lumping" or aggregation are given by Smith (1975) and Proctor and Redfern and James F. MacLaren (1976a, 1976b). In general, outlet hydrographs using only one subcatchment and one or no gutter/pipes are almost identical to those resulting from a detailed schematization using several subcatchments and gutter/pipes. A key parameter to be adjusted is the subcatchment width. Quality comparisons may be more variable depending upon how the several land uses and/or pollutant loading rates are aggregated.

OUTPUT

Output from single event simulation consists basically of generated hydrographs and pollutographs printed for the whole event at a specified interval of time steps (e.g., every time step). Continuous SWMM retains this option for up to five user-specified date intervals. In addition, daily, monthly, annual, and grand total values for runoff, precipitation, and pollutant loads are provided. Daily totals are printed whenever there is runoff and/or precipitation.

In addition, the fifty highest hourly totals are listed, by both runoff volume and biochemical oxygen demand (BOD) load. These may be compared to the fifty highest hourly rainfall depths and may be used in selecting critical time periods for more detailed study. For example, a two-year simulation of a 312-acre (126-hectare) catchment tributary to Lake Calhoun in Minneapolis was made, and the ten highest rainfall, runoff, and BOD loads (from the output of the fifty highest) are shown in table 1. The comparisons indicate that the rankings differ according to antecedent conditions affecting each parameter. For example, the storm producing the most rain resulted in the third highest runoff and second highest BOD. The table adds further justification to the contention that it is necessary to treat rainfall, runoff, and pollutant loads separately in statistical analyses.

Future work will add more statistical features to the model, including separation of storm "events" by means of a specified interevent time. Such analyses will be made suitable for all SWMM blocks, not just the Runoff Block as at present.

DRY PERIOD REGENERATION

Quantity

Infiltration capacity is regenerated during dry periods, assuming an exponential "drying curve" analogous to the "wetting curve" of Horton's equation. Monthly evaporation totals are used to regenerate depression storage on both pervious and impervious areas and are also considered an initial "loss" for each time step showing rainfall. Computations are bypassed during dry periods if infiltration and depression storage regeneration is complete.

Quality

Regeneration of pollutant loadings on the subcatchment surfaces during dry time steps (i.e., steps when there is no runoff) is calculated depending upon how the loadings are figured initially. If dust and dirt and pollutant fraction parameters are used, as in the past, they determine the rate of regeneration, in mg./day. If initial pollutant loads are simply used as input for each subcatchment in lb./ac., they are divided by the input value

TABLE 1

Hourly Event Ranking by Rain, Flow, and BOD for Two Year Simulation of Lake Calhoun Catchment, Minneapolis

Ten highest values are taken from the tabulated output of 50 highest given by SWMM

RANK	DATE	HR.	RAIN(IN./HR.)	DATE	HR.	FLOW(IN./HR.)	DATE	HR.	BOD(LB./MIN.)
1	7/20/51	22	0.98	7/21/51	2	0.543	5/15/51	22	16.78
2	7/21/51	1	0.80	7/20/51	23	0.429	7/20/51	22	12.88
3	7/22/50	15	0.79	7/20/51	22	0.392	7/16/51	2	9.62
4	7/30/51	8	0.65	5/15/51	22	0.383	7/20/51	23	7.64
5	5/15/51	21	0.63	7/21/51	1	0.320	5/15/51	21	6.19
6	7/21/51	2	0.56	7/30/51	8	0.295	9/08/51	20	5.70
7	9/11/51	23	0.55	7/16/51	2	0.254	7/22/51	15	5.43
8	8/07/51	18	0.54	7/22/51	16	0.253	7/30/51	8	5.42
9	5/05/50	10	0.49	5/18/51	16	0.238	5/05/50	10	5.25
10	6/25/51	24	0.49	7/22/50	15	0.221	7/22/50	16	5.11

of DRYDAY (number of preceding dry days) to determine the regeneration rate. Catchbasin loads are regenerated in the latter fashion. There is no upper limit on surface loads; other than by runoff, they may be reduced only by street sweeping. Catchbasin loads are limited to their initial values.

Street sweeping occurs at intervals specified for each land use. The intervals are computed on the basis of intervening dry time steps. A dry time step here is one in which the subcatchment receives no precipitation and has no water remaining as snow or stored in impervious depressions. When snowmelt is simulated, street sweeping may be bypassed for a specified interval of the year (e.g., the winter months).

Runoff simulates eight quality parameters, as in the past, plus, optionally, erosion using the Universal Soil Loss Equation and a pollutant specified by the user. The latter could be used to simulate chlorides, for instance, or any other desired parameter measurable in mg./l. At the user's option, regeneration during dry periods will appear only when snow is present.

CONTINUOUS SWMM COMPARED TO OTHER MODELS

Preliminary comparisons of SWMM and STORM, without Storage/Treatment simulation, indicate that the two outputs are comparable and STORM is cheaper by approximately 50%. Why, then, might SWMM be used instead of STORM or other existing continuous models? When just the Runoff Block is required, STORM may well be the choice because of its simplicity, good documentation, useful output, and inclusion of the SCS method for rural runoff generation. SWMM might be preferred if flow routing in gutter/pipes were desired or particular features of runoff or quality generation were needed. In addition, SWMM now couples both the single event and continuous simulation capability into one model.

The principal advantage of continuous SWMM lies in its Storage/Treatment block. Varying pathways among and through the storage and treatment devices may be followed instead of the fixed configuration of STORM. Most importantly, the treatment that occurs in storage may be simulated by SWMM, as may sludge generation by all control options. A future SWMM version will compute operating and maintenance costs on the basis of actual hours of operation of wet weather treatment devices, providing more realistic cost data. The future statistical procedures mentioned in conjunction with Runoff output may also be applied to Storage/Treatment.

SUMMARY

SWMM is only one of several available urban runoff models, and no claims may be made that it is "best" or unique. Third parties have improved it by suggestions and development of its capabilities; continuous simulation is no exception. With this capability, plus snowmelt, improved Storage/Treatment, and other features, SWMM does stand as one of the most versatile of available models.

NOTE

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